4.8 Extreme Temperatures

4.8.1 Description

Extreme temperatures are relative to the usual weather in the region based on climatic averages.

4.8.1.1 Extreme Heat

Extreme heat for Massachusetts is usually defined as a period of three or more consecutive days above 90 degrees.

When an excessive heat event is forecast, National Weather Service may issue an Excessive Heat Watch or an Excessive Heat Warning.

- Excessive Heat Watch: An Excessive Heat Watch is issued when there is a potential for the heat index value to reach or exceed 110 degrees Fahrenheit within the next 24 to 48 hours.
- Excessive Heat Warning: An Excessive Heat Warning is issued when the heat index value is expected to reach or exceed 110 degrees Fahrenheit within the next 12 to 24 hours. An Excessive Heat Warning may be issued for lower criteria if it is early in the season or during a multi-day heat wave.

4.8.1.2 Extreme Cold

Extreme cold may cause "cold stress" which includes frostbite and hypothermia. Cold stress occurs by driving down the skin temperature, and eventually the internal body temperature. When the body is unable to warm itself, serious cold-related illnesses and injuries may occur, and permanent tissue damage and death may result.

Increased wind speed also causes heat to leave the body more rapidly (wind chill effect). Wind Chill Temperature is the temperature that people and animals feel when they are outside, and it is based on the rate of heat loss from exposed skin by the effects of wind and cold. As the wind increases, the body loses heat at a faster rate, causing the skin's temperature to drop.

When an extreme cold event is forecast, NWS may issue a Wind Chill Advisory or a Wind Chill Warning.

- Wind Chill Advisory: A Wind Chill Advisory is issued when wind chill temperatures are potentially hazardous. Wind chill index between -15 degrees and -24 degrees for at least three hours using on the sustained wind.
- Wind Chill Warning: A Wind Chill Warning is issued when wind chill temperatures are life threatening. Generally, a Wind Chill Warning is issued when the wind chill index of less than or equal to 25 degrees for at least three hours using only sustained wind.

4.8.2 Location

According to the NOAA, Massachusetts is made up of three climate divisions: Western, Central, and Coastal. Average annual temperatures vary slightly over the divisions, with annual average

temperatures of around 46°F in the Western division, 49°F in the Central division, and 50°F in the Coastal division.

Heat impacts can be particularly significant in urban areas. Approximately half of the world's population lives in these heavily developed areas, with that number increasing to 74 percent in developed nations. As these urban areas develop and change, so does the landscape. Buildings, roads, and other infrastructure replace open land and vegetation. Surfaces that were once permeable and moist are now impermeable and dry. Dark-colored asphalt and roofs also absorb more of the sun's energy. These changes cause urban areas to become warmer than the surrounding areas. This forms "islands" of higher temperatures, often referred to as "heat islands."

The term "heat island" describes built-up areas that are hotter than nearby rural or shaded areas. The annual mean air temperature of a city with more than 1 million people can be between 1.8°F and 5.4°F warmer than its surrounding areas. In the evening, the difference in air temperatures can be as high as 22°F. Heat islands occur on the surface and in the atmosphere.

All of Massachusetts is susceptible to extreme cold each winter. The arctic air can cross all portions of the Commonwealth, and together with brisk winds, can lead to dangerously cold wind chill values.

According to a University of Massachusetts study (https://climateactiontool.org), extreme winter temperatures in Massachusetts and the northeast region observed during recent years are thought to be the result of rapid warming in the Arctic, which has impacts on the strength and direction of the jet stream.

Research on extreme temperature events suggest that it is likely that the region will continue to experience extreme winter temperatures in varying levels of both frequency and intensity. In recent years, the "Polar Vortex" has been the reason the region has experienced severe cold. The Polar Vortex is described as an area of low pressure and cold air surrounding the north pole. Once the area of low pressure becomes less stable, it expands sending the extreme cold air southward over the United States.

4.8.3 Extent

A heat wave is defined as 3 or more days of temperatures of 90°F or above. A basic definition of a heat wave implies that it is an extended period of unusually high atmosphere-related heat stress, which causes temporary modifications in lifestyle and which may have adverse health consequences for the affected population.

The NWS issues a Wind Chill Advisory if the Wind Chill Index is forecast to dip to –15°F to –24°F for at least 3 hours, based on sustained winds (not gusts). The NWS issues a Wind Chill Warning if the Wind Chill Index is forecast to fall to –25°F or colder for at least 3 hours. On November 1, 2001, the NWS implemented a Wind Chill Temperature Index designed to more accurately calculate how cold air feels on human skin.

4.8.4 Previous Occurrences

According to the NOAA's Storm Events Database, accessed in March 2018, there have been 43 warm weather events (ranging from Record Warmth/Heat to Excessive Heat events) since 1995. The most current event in the database occurred in July 2013. Excessive heat results from a combination of temperatures well above normal and high humidity. Whenever the heat index values meet or exceed

locally or regionally established heat or excessive heat warning thresholds, an event is reported in the database.

In 2012, Massachusetts temperatures broke 27 heat records. Most of these records were broken between June 20 and June 22, 2012, during the first major heat wave of the summer to hit Massachusetts and the East Coast. In July 2013, a long period of hot and humid weather occurred throughout New England. One fatality occurred on July 6, when a postal worker collapsed as the Heat Index reached 100°F.

Since 1994, there have been 33 cold weather events within the Commonwealth, ranging from Cold/Wind Chill to Extreme Cold/Wind Chill events. Detailed information regarding most of these extreme temperature events was not available; however, additional detail on recent extreme events is provided below.

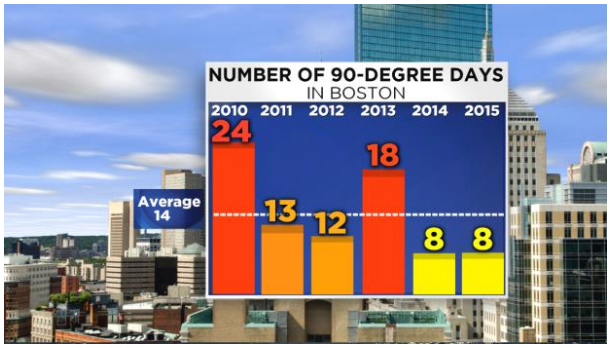
In February 2015, a series of snowstorms piled nearly 60 inches on the city of Boston in 3 weeks and caused recurrent blizzards across eastern Massachusetts. Temperature gauges across the Commonwealth measured extreme cold, with wind chills as low as -31°F. Four indirect fatalities occurred as a result of this event: two adults died shoveling snow and two adults were hit by snowplows.

In February 2016, one cold weather event broke records throughout the state. Wind chill in Worcester was measured at -44°F, and the measured temperature in Boston (-9°F) broke a record previously set in 1957. Extreme cold/wind chill events were declared in 16 climate zones across the Commonwealth.

4.8.5 Probability of Future Events

Massachusetts has averaged 2.4 declared cold weather events and 0.8 extreme cold weather events annually between January 2013 and October 2017. The year 2015 was a particularly notable one, with seven cold weather events, including three extreme cold/wind chill events, as compared to no cold weather events in 2012 and one in 2013. Although hot weather events are declared less often in Massachusetts, Figure 19 below, shows the frequency of 90-degree days (the criteria for a heat wave) since 2010. Considering that three of these days comprise a heat wave, it would be assumed that an average of between four and five heat waves occur annually in Massachusetts.

Figure 19: Number of 90 Degree Days in Boston



4.8.6 Vulnerability and Risk Assessment

4.8.6.1 Hazard Ranking

The priority hazard ranking process for the 2018 HIRA determined extreme temperatures to be a low priority hazard in Massachusetts, as seen in Table 54.

Table 54: Extreme Temperatures Hazard Priority

Jurisdiction	Likelihood of Hazard Occurrence	Likely Range of Impact	Consequence Analysis					Composite Hazard Index
			Populations (Injuries and Deaths)	Government	Built Environment	Natural Resources & Environment	Economy	
Barnstable	**Likely** *Between 10% to 100% probability within next 12-60 months*	**Small** *Less than 10% of the total jurisdictional boundaries*	**Negligible** *Minor or no injuries*	**Negligible** *Minor or no impacts, lasting for very short time*	**Negligible** *Low impact to infrastructure, Less than 10% structures damaged*	**Limited** *Less than 20% of land or natural resources impacted*	**Negligible** *Minor or no impacts to business, low damage/ replacement costs, very little recovery needed*	**Low**
Berkshire								
Bristol								
Dukes								
Essex								
Franklin								
Hampden								
Hampshire								
Middlesex								
Nantucket								
Norfolk								
Plymouth								
Suffolk								
Worcester								

4.8.6.2 Risk and Vulnerability to Populations

According to the Centers for Disease Control and Prevention, populations most at risk to extreme cold and heat events include the following: (1) people over the age of 65, who are less able to withstand temperatures extremes due to their age, health conditions, and limited mobility to access shelters; (2) infants and children under 5 years of age; (3) individuals with pre-existing medical conditions that impair heat tolerance (e.g., heart disease or kidney disease); (4) low-income individuals who cannot afford proper heating and cooling; (5) people with respiratory conditions, such as asthma or chronic obstructive pulmonary disease; and (6) the general public who may overexert themselves when working or exercising during extreme heat events or who may experience hypothermia during extreme cold events. Additionally, people who live alone—particularly the elderly and individuals with disabilities—are at higher risk of heat-related illness due to their isolation and reluctance to relocate to cooler environments. In addition, the urban heat island effect can exacerbate vulnerability to extreme heat for populations in urban areas. Lastly, those without adequate shelter, including homeless populations, are also at greater risk. According to data from the U.S. Department of Housing and Urban Development, 17,565 people experienced homelessness during a point-in-time count conducted in January 2017 (US HUD, 2017).

4.8.6.3 Risk and Vulnerability to Built Environment (Property, Structures, and Critical Facilities)

All elements of the built environment are exposed to the extreme temperature hazard, including state-owned critical facilities. The impacts of extreme heat on buildings include: increased thermal stresses on building materials, which leads to greater wear and tear and reduces a building's useful lifespan; increased air-conditioning demand to maintain a comfortable temperature; overheated heating, ventilation, and air-conditioning systems; and disruptions in service associated with power outages (resilient MA, 2018).

Extreme cold temperature events can damage buildings through freezing or bursting pipes and freeze and thaw cycles. Additionally, manufactured buildings (trailers and mobile homes) and antiquated or poorly constructed facilities may not be able to withstand extreme temperatures. Extreme cold can cause materials such as plastic to become less pliable, increasing the potential for these materials to break down during extreme cold events (resilient MA, 2018).

4.8.6.4 Risk and Vulnerability to Natural Resources and the Environment

There are numerous ways in which changing temperatures will impact the natural environment. Crops are vulnerable to extreme heat and cold. Each plant species has a different tolerance to hot and cold temperatures. Because the species that exist in a given area have adapted to survive within a specific temperature range, extreme temperature events can place significant stress both on individual species and the ecosystems in which they function. High-elevation spruce-fir forests, forested boreal swamp, and higher-elevation northern hardwoods are likely to be highly vulnerable to climate change (MCCS and DFW, 2010). Higher summer temperatures will disrupt wetland hydrology.

4.8.6.5 Risk and Vulnerability to Government Operations

All state-owned buildings are exposed to the extreme temperature hazard. Government operations may be faced with increased financial burdens due to unexpected building repairs (e.g., repairs for

burst pipes), higher than normal utility bills, or operational interruptions due to power failure (i.e., loss of electricity and telecommunications).

Extreme heat will result in an increased demand for cooling centers and air conditioning. Extreme heat events can sometimes cause short periods of utility failure, commonly referred to as brownouts, due to increased usage of air conditioners, appliances, and other items requiring power.

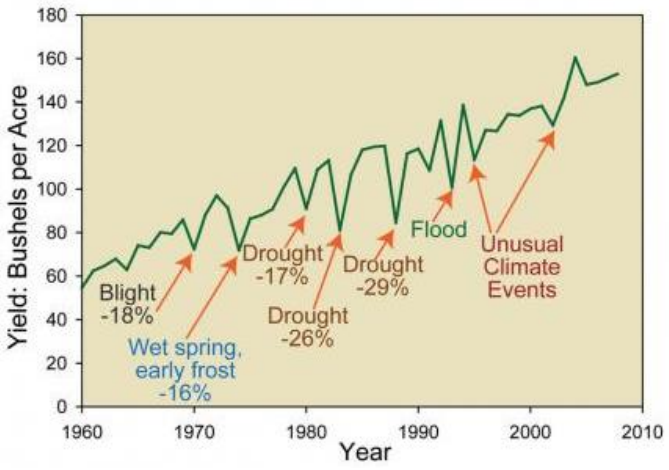
Extreme cold temperature events can damage buildings through freezing or bursting pipes and freeze and thaw cycles. Additionally, manufactured buildings (trailers and mobile homes) and antiquated or poorly constructed facilities may not be able to withstand extreme temperatures. The heavy snowfall and ice storms associated with extreme cold temperature events can also cause power interruptions. Backup power is recommended for critical facilities and infrastructure.

4.8.6.6 Risk and Vulnerability to Economy

Extreme temperature events also have impacts on the economy, including loss of business function and damage to and loss of inventory. Business owners may be faced with increased financial burdens due to unexpected building repairs (e.g., repairs for burst pipes), higher than normal utility bills, or business interruptions due to power failure (i.e., loss of electricity and telecommunications). Increased demand for water and electricity may result in shortages and a higher cost for these resources. Industries that rely on water for business (e.g., landscaping businesses) will also face significant impacts. There is a loss of productivity and income when the transportation sector is impacted and people and commodities cannot get to their intended destination. Even though most businesses will still be operational, they may be impacted aesthetically if extreme temperatures damage landscaping around their buildings. Businesses with employees that work outdoors (such as agricultural and construction companies) may have to reduce employees' exposure to the elements by reducing or shifting their hours to cooler or warmer periods of the day.

The agricultural industry is most directly at risk in terms of economic impact and damage due to extreme temperature events. Extreme heat can result in drought and dry conditions, which directly impact livestock and crop production. Increasing average temperatures may make crops more susceptible to invasive species (see Section 4.3.3 for additional information). Higher temperatures that result in greater concentrations of ozone negatively impact plants that are sensitive to ozone (USGCRP, 2009). Additionally, changing temperatures can impact the phenology (cyclic and seasonal natural phenomena, especially in relation to climate and plant and animal life). The impact of temperature anomalies and associated climate events on crop yields is shown in Figure 20.

Figure 20: Impact of Extreme Weather Events on U.S. Corn Yields, 1960 to 2008; Drought and Climate Events on Crop Yields



Source: USGCRP, 2009

Livestock are also impacted, as heat stress can make animals more vulnerable to disease, reduce their fertility, and decrease the rate of milk production. Additionally, scientists believe the use of parasiticides and other animal treatments may increase as the threat of invasive species grows. Increased use of these treatments increases the risk of pesticides entering the food chain and could result in pesticide resistance, which could result in additional economic impacts on the agricultural industry.